Event Rates at the Galactic Center: a UKIRT near-IR Survey

Geoffrey Bryden
Jet Propulsion Laboratory

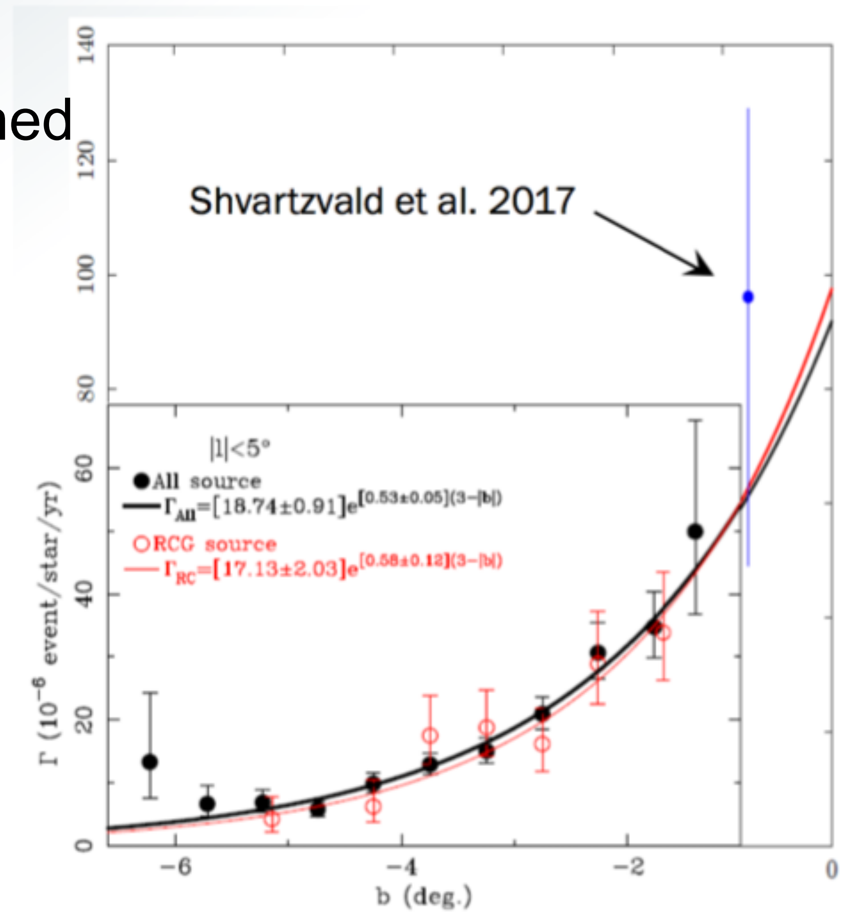
UKIRT microlensing team:

Yossi Shvartzvald, Sebastiano Calchi Novati, Savannah Jacklin, Calen Henderson, Scott Gaudi, Matthew Penny, David Nataf, Chas Beichman, Kiri Wagstaff

Microlensing 21 Flashback

Yossi introduced the survey last year:

- Initial analysis of a few low-b fields, ~5% of total dataset
- Discovery of 5 highly-extinguished low-b microlensing events
- Preliminary estimate of the event rate at b ≈ 1°



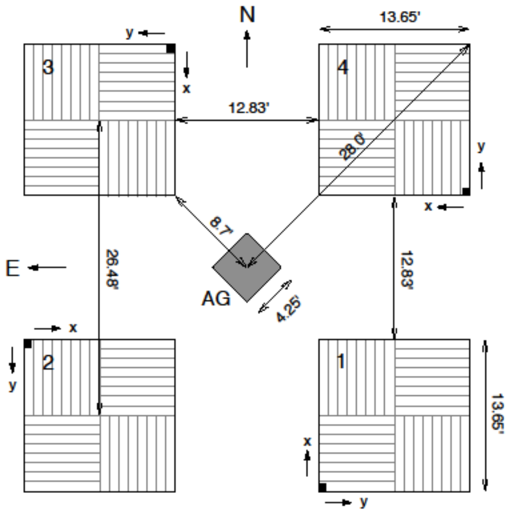
A Near-IR Survey with UKIRT

UKIRT telescope:

- 3.8m NIR telescope @ Mauna Kea
- Average seeing ~0.8”

WFCAM camera:

- Four NIR detectors
- 0.4”/pixel
- Four exposures covers 0.75 sq.deg
- Available filters – *ZYJHK*



Scientific goals of UKIRT survey

NIR event rate as a function of (*l*,*b*):

- Crucial for *WFIRST* field optimization
- Combined with dust models → Galactic structure

Event timescale as a function of (*l*,*b*):

- Bulge-bulge events are expected to be shorter (Gould 1995)

NIR coverage of events:

- Source color - for Einstein radius (with finite source effects)
- NIR source flux - for future AO lens flux measurements

New science:

- High cadence (daily) observations of unexplored regions (Galactic center).

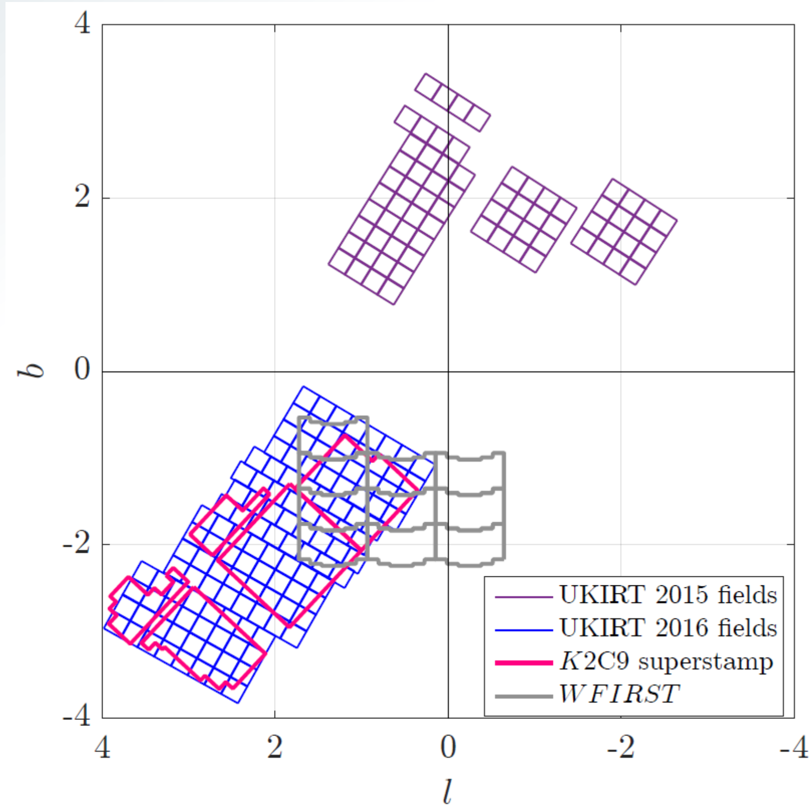
UKIRT 2015-2016 microlensing surveys

2015 survey – *Spitzer*:

- Area: 3.4 deg^2
- Duration: 39 nights
- Cadence: 5 epochs/night
- Total epochs per field: ~145
- Filter: *H*

2016 survey – *K2C9*:

- Area: 6.0 deg^2
- Duration: 91 nights
- Cadence: 2-3 epochs/night
- Total epochs per field: ~160
- Filter: *H*

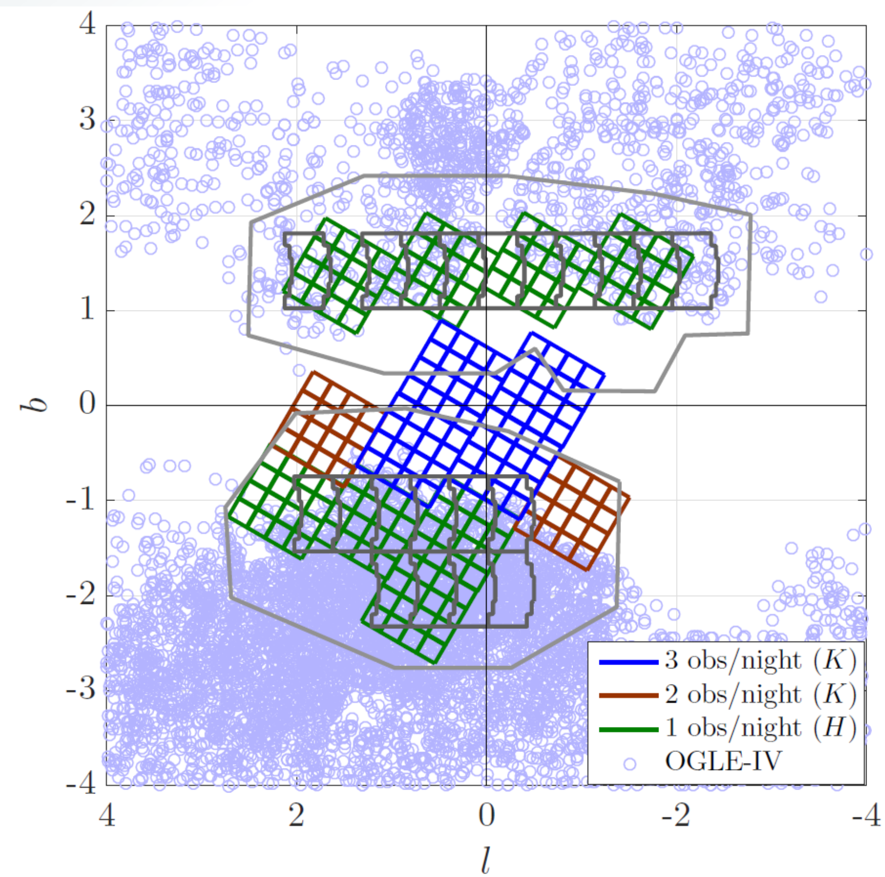


Shvartzvald et al. 2017

UKIRT 2017(-2019) microlensing surveys

2017:

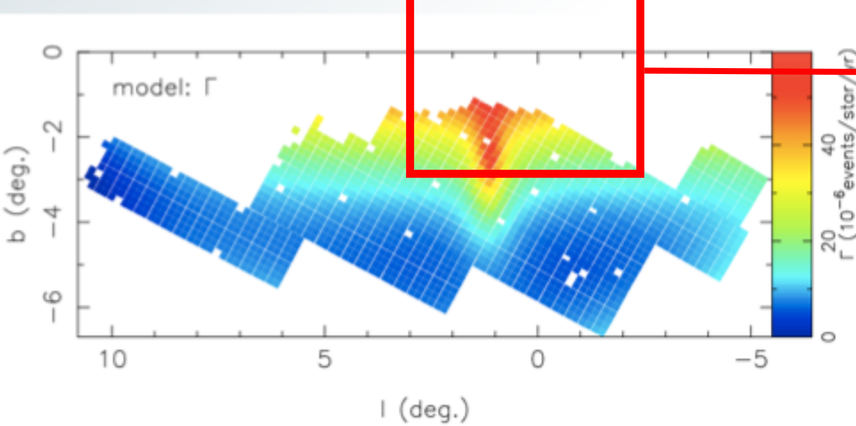
- Area: 10.5 deg^2
- Dates: 20/Apr (4/May) – 30/Aug
- Duration: 133 nights
- Cadence: 1-3 epochs/night
- Filters: *H* / *K*



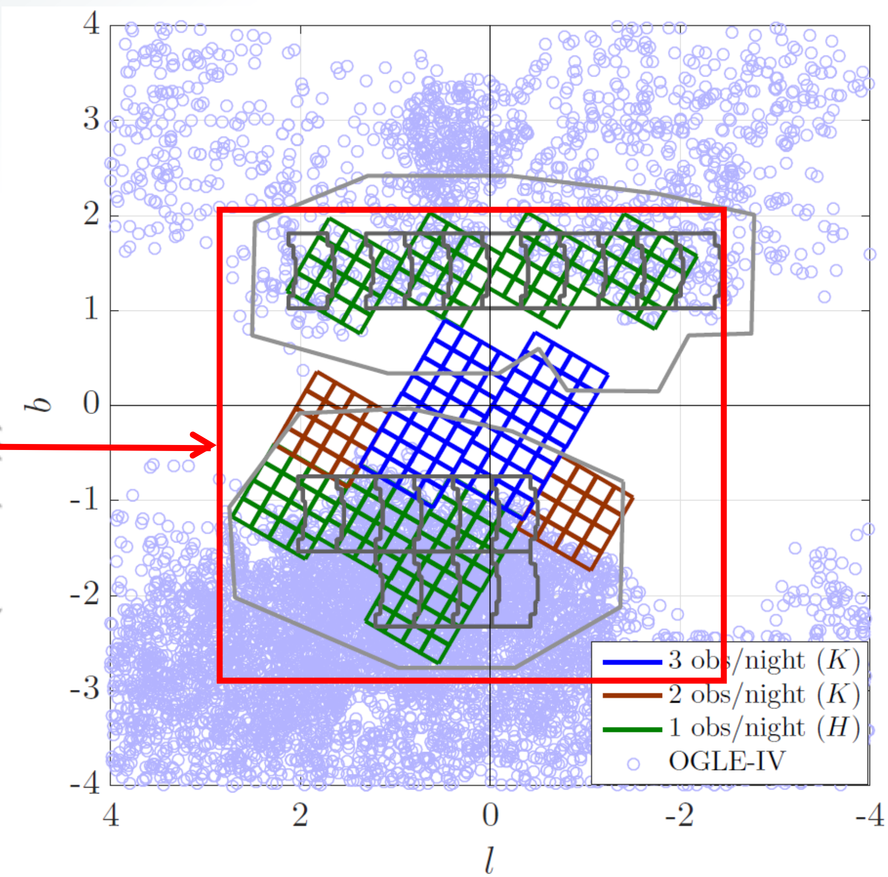
UKIRT 2017(-2019) microlensing surveys

2017:

- Area: 10.5 deg^2
- Dates: 20/Apr (4/May) – 30/Aug
- Duration: 133 nights
- Cadence: 1-3 epochs/night
- Filters: *H* / *K*



Sumi & Penny 2016



Photometry

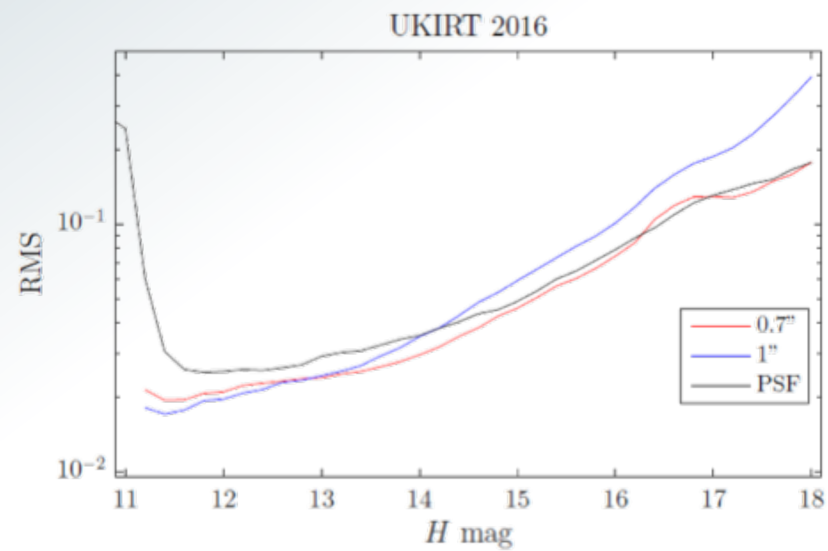
Photometry methods:

1. Soft-edged aperture photometry by CASU (Hodgkin et al. 2009)
    - Several apertures: 0.5'', 0.7'', 1'', 1.4''….
    - 2MASS calibrated
    - Spatial distortion corrected
2. PSF photometry using Sextractor (Bertin & Arnouts 1996) and PSFEx (Bertin 2011)
    - ~2MASS calibrated
3. DIA photometry for specific events using pySis (Albrow et. al. 2009)

Photometry – CASU vs. PSF

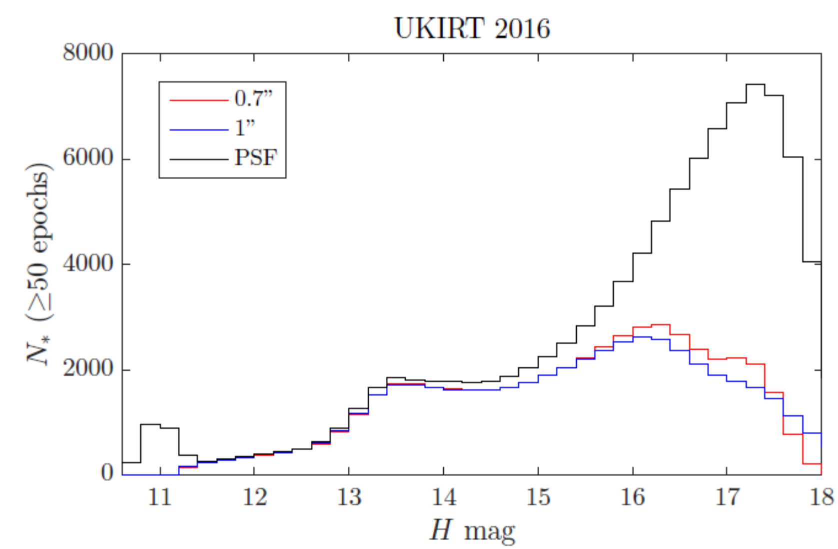
Precision:

- Reaching <2% level
- CASU is better at H<14.5



Source detection:

- Number of sources similar for H<15
- PSF much better for faint sources
- In total, almost twice as many sources with PSF
- Red clump excess around H=13.5



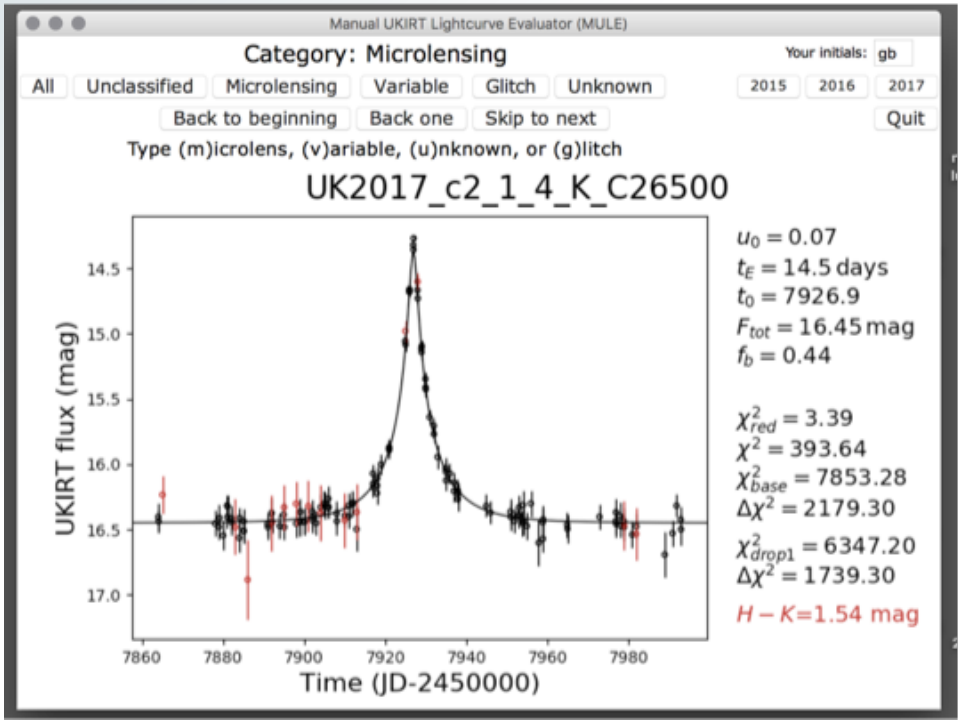
Event detection

- Event finder similar to KMT (Kim et al. 2018), based on a 2-D (t_0, t_{eff}) grid search
- Conservative detection threshold: $\Delta\chi^2 > 500$
- Challenges: outliers, variable stars, long events

Event Detection Statistics			
Season	**Location**	**Lightcurves**	**Candidates**
2015	North	6.7M	563
2016	South	11.3M	845
2017	N+S+Central	18.1M	3352

Manual UKIRT Lightcurve Evaluator (MULE)

For now we are using a python-based GUI to identify microlensing events among the candidate lightcurves **by eye**.



We are implementing a **machine-learning** classification system.

Current results with a random forest classifier (cf. Wyrzykowski+ 2015) are promising (false positive/negative rates below 20%), but are limited by the information content within the chosen set of lightcurve features. New metrics need to be included.

UKIRT microlensing events

2015:

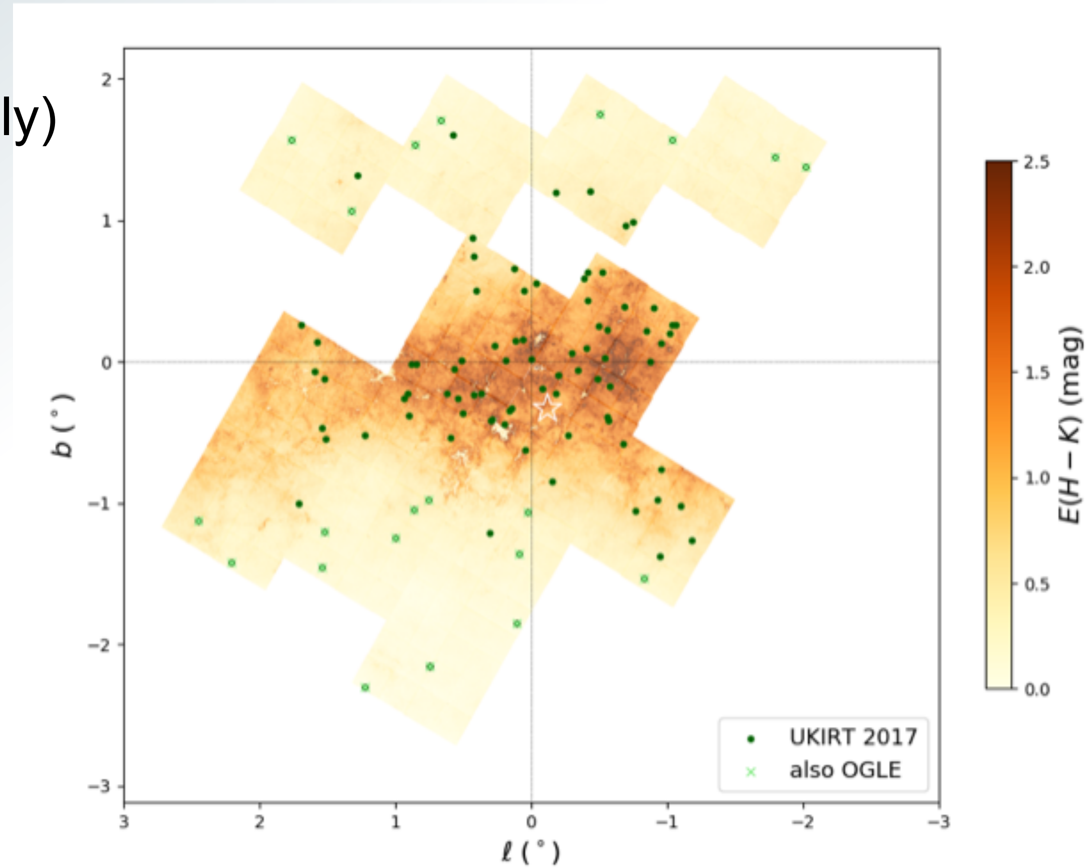
- North – 13 (4 UKIRT-only)

2016:

- South – 53 (16)

2017:

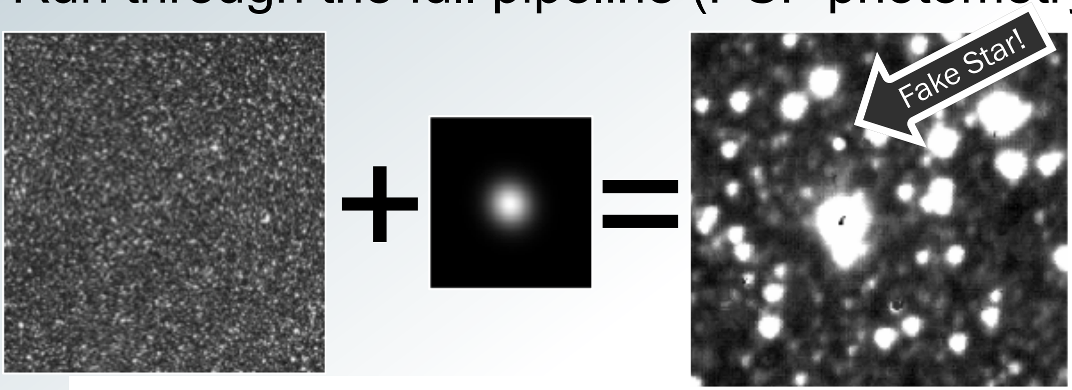
- North – 16 (8)
- **Central – 69 (68)**
- South – 26 (16)

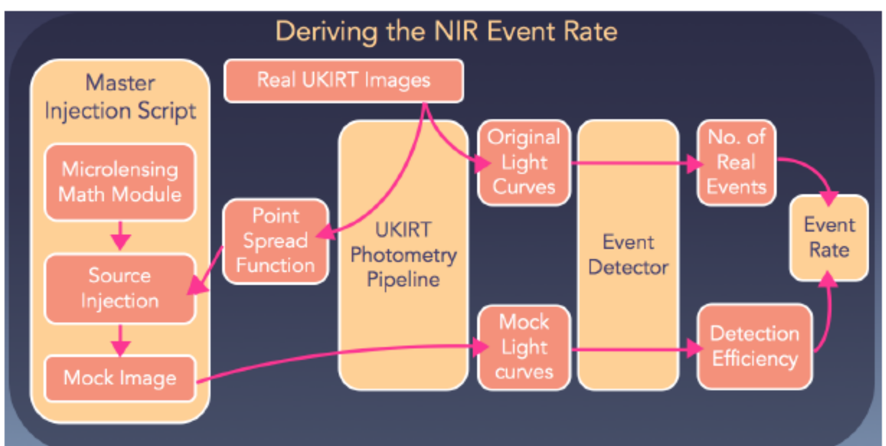


Detection efficiency – Future work

Image level injection/recovery:

- Event injections – using PSF templates from PSFEx
- Run through the full pipeline (PSF photometry + event detection)



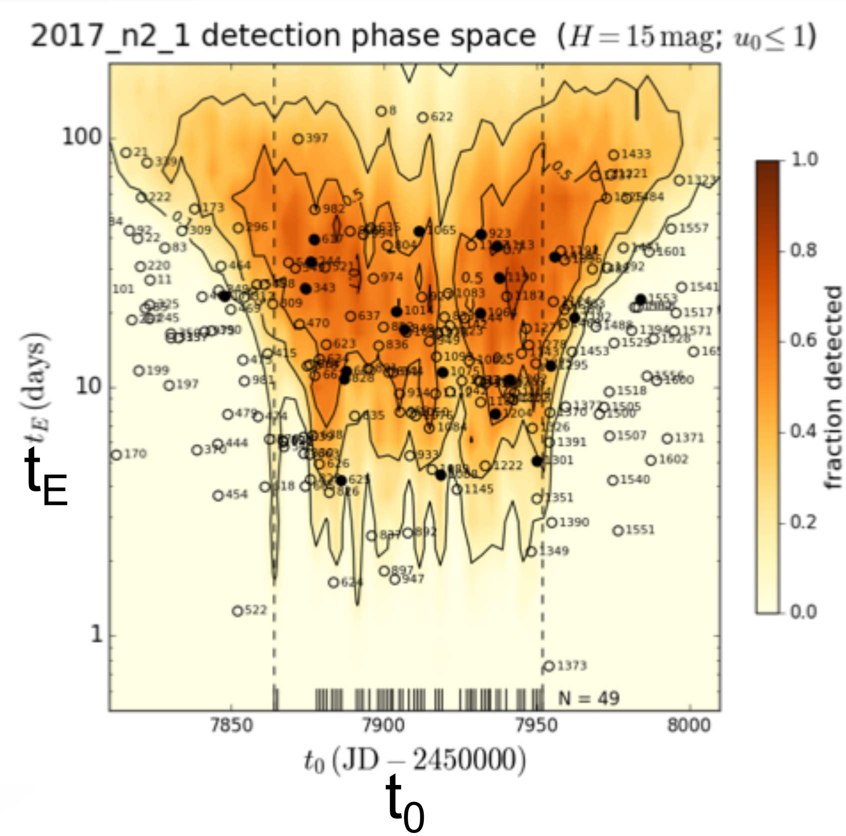


Savannah Jacklin
PhD student
Vanderbilt

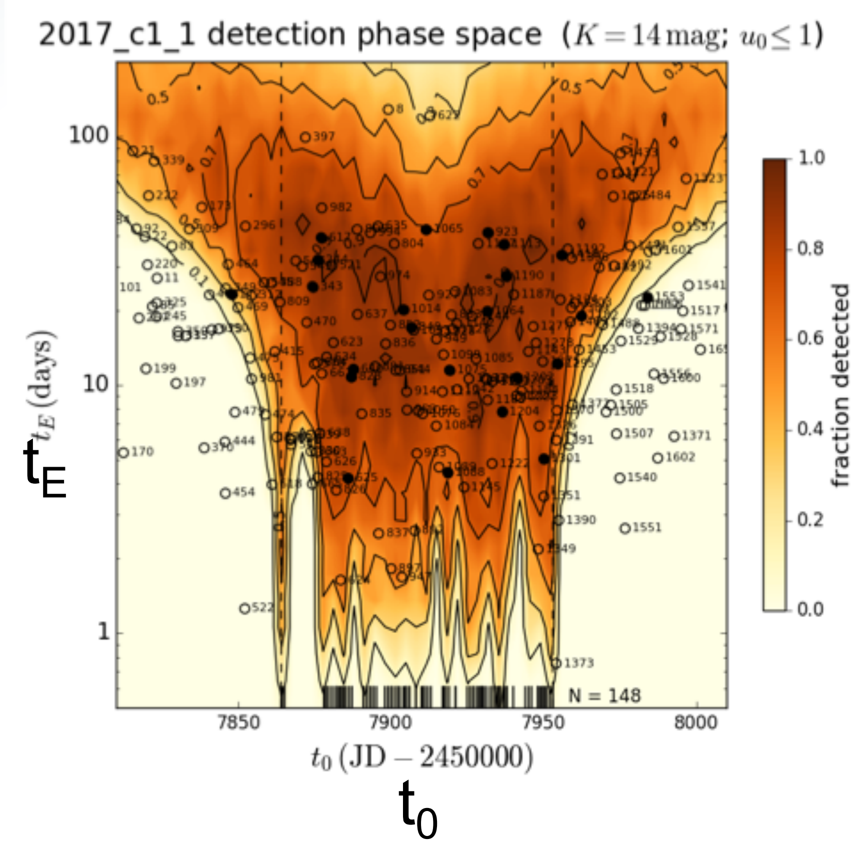
Detection efficiency

Lightcurve-level detection simulations:

Northern fields

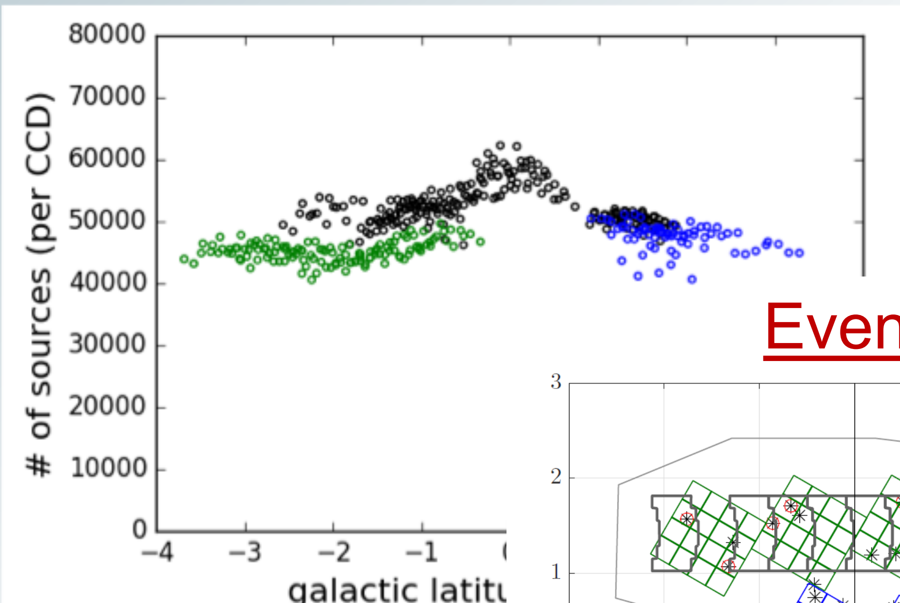


Central fields

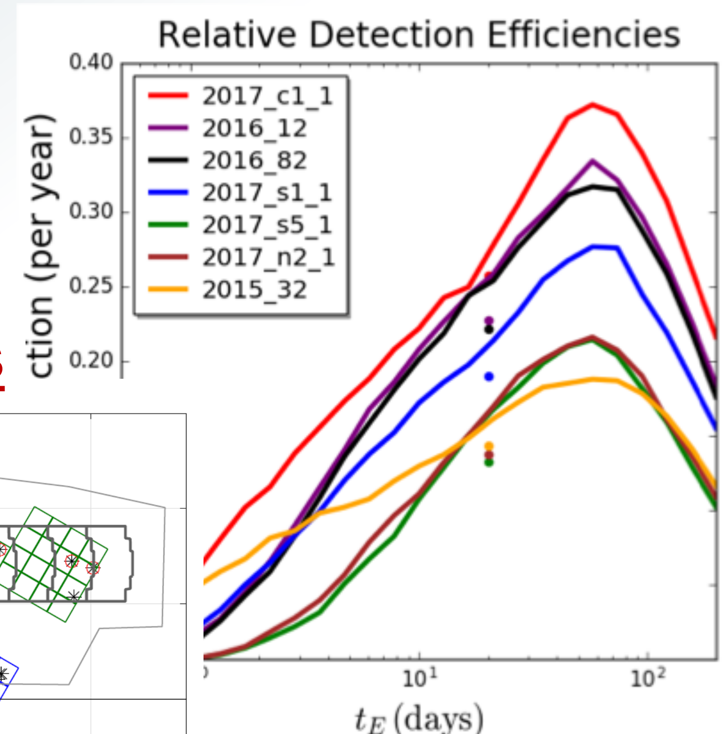


Near-IR event rate

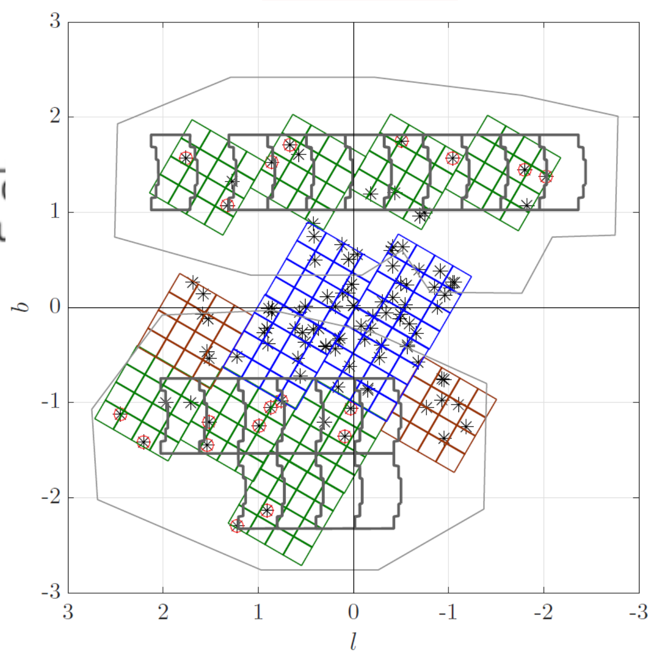
Source density



Detection efficiency



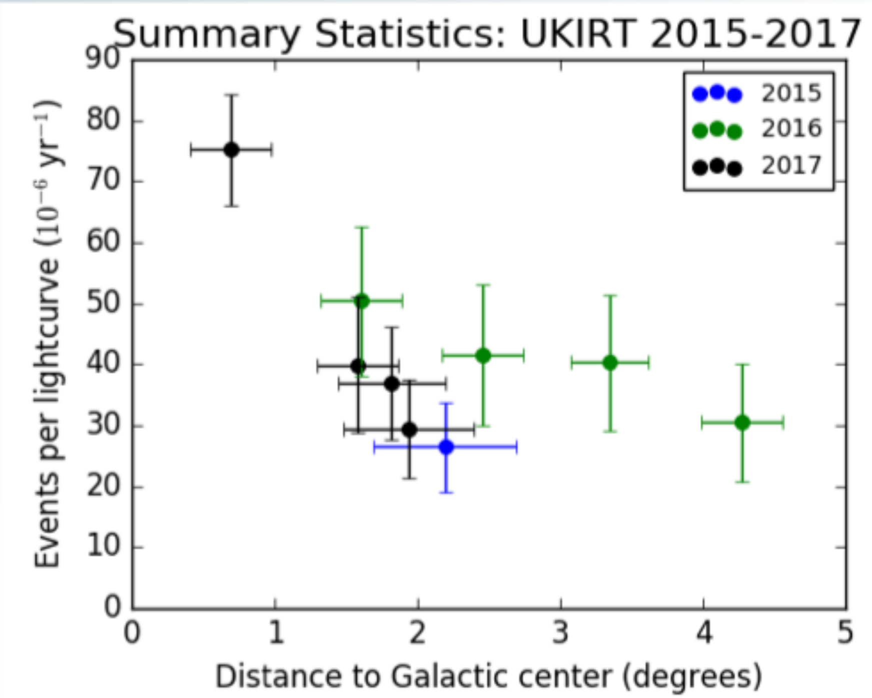
Events

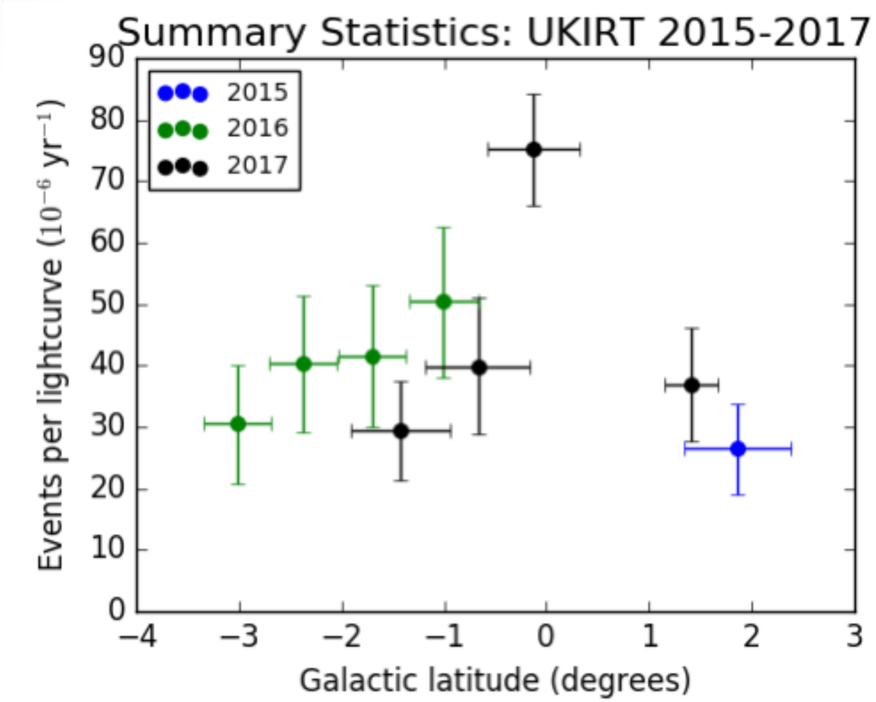


Near-IR event rate

Preliminary results:

1. High event rate in the central fields
2. No excess of events in the northern bulge





Additional Science

<u>2015:</u>

- A massive remnant in wide binary:

  OGLE-2015-1285 (Shvartzvald et al. 2015)

<u>2016:</u>

- Planets:

  MOA-2016-227 (Koshimoto et al. 2017)

  OGLE-2016-0163 (Han et al. 2017)

  OGLE-2016-1190 (Ryu et al. submitted)

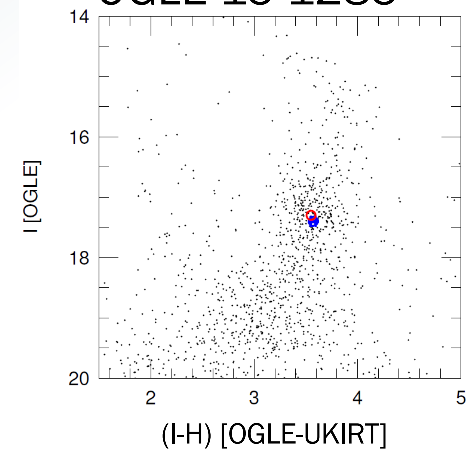
  OGLE-2016-0241 (Poleski et al. in prep.)

<u>2017:</u>

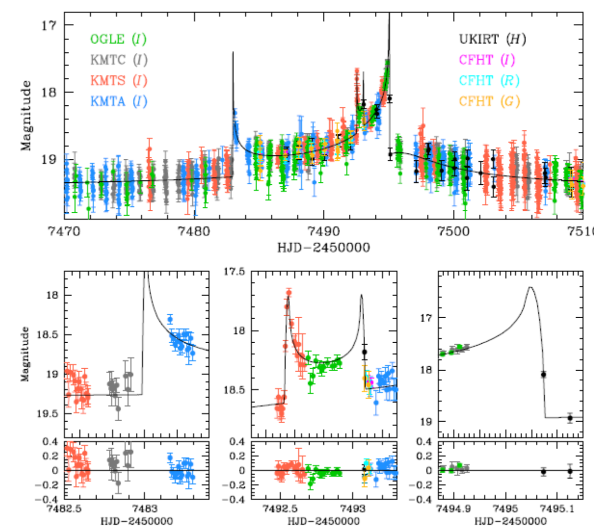
- Planet:

  OGLE-2017-0173 (Hwang et al. 2017)

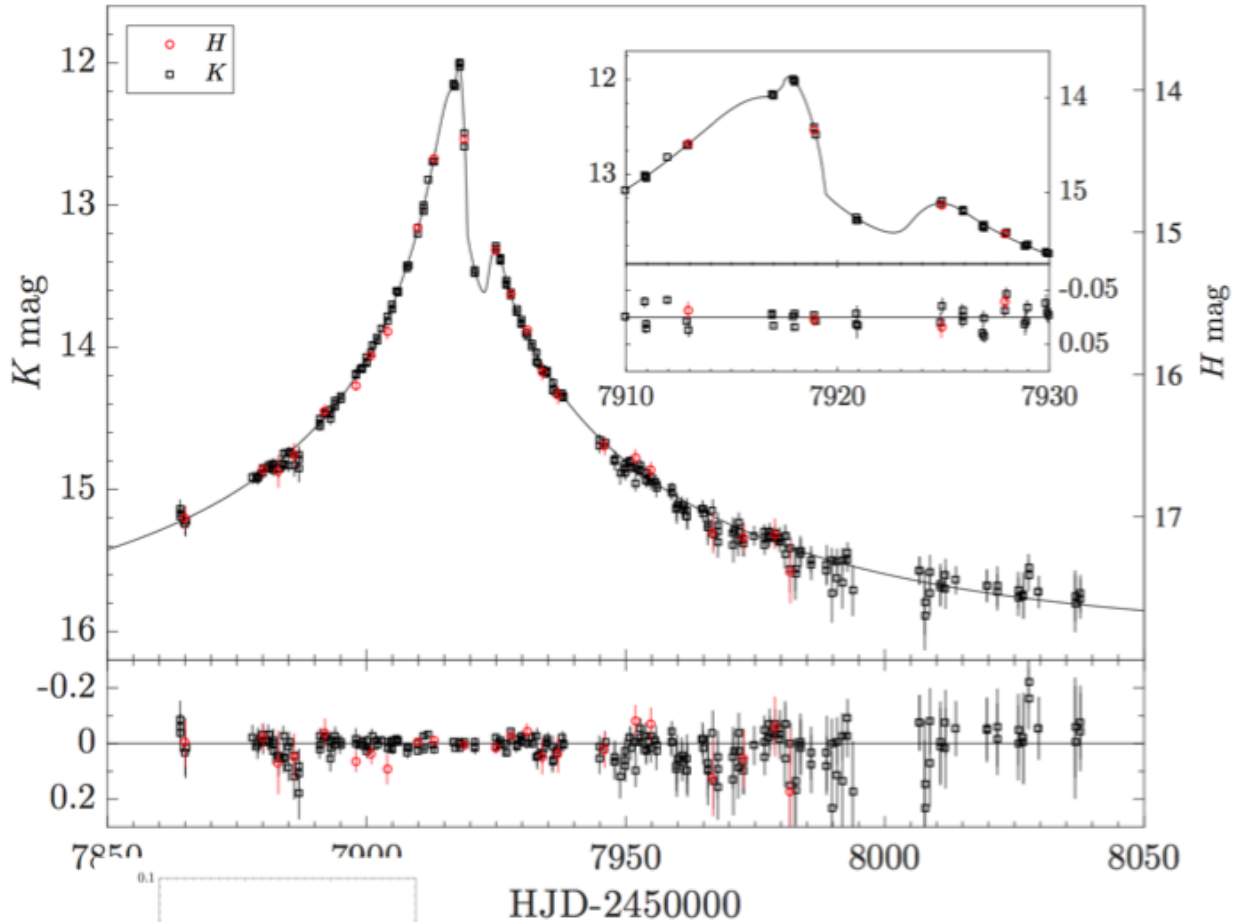
OGLE-15-1285

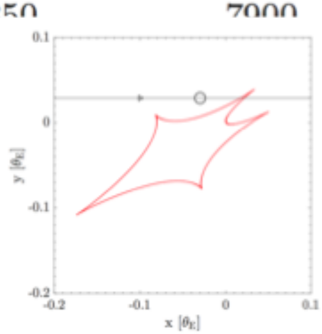


OGLE-16-0163



UKIRT-2017-BLG-001b

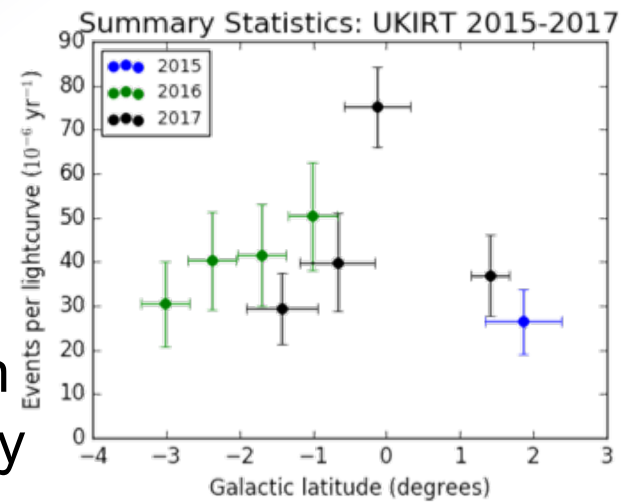




Shvartzvald et al. 2018

Summary

- 2017 survey of the galactic center (inner 1°) finds a high microlensing rate
- 2018 survey will repeat these fields, adding baseline and improving statistics
- We will meanwhile improve the analysis
  - lower detection thresholds
  - machine learning for event classification
  - injection/recovery for detection efficiency



- Variable extinction is problematic (see next talk)
- Lightcurves are publicly available in the NASA Exoplanet Archive (see next next talk)https://exoplanetarchive.ipac.caltech.edu/docs/UKIRTMission.html https://exoplanetarchive.ipac.caltech.edu/cgi-bin/TblSearch/nph-tblSearchInit?app=ExoTbls&config=ukirttimeseries